NGS Antenna Calibration Procedures

Procedures Document
National Geodetic Survey
National Ocean Service
National Oceanic and Atmospheric Administration

AUTHORIZED BY:

FANCHER.KENDALL.L.1365866526

Digitally signed by FANCHER.KENDALL.L.1365866526
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Chief, Instrumentation and Methodologies Branch **Date**

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Purpose/Scope: This procedures document provides guidance on how NGS may, at its discretion, provide antenna calibration services to the general public. The document outlines eligibility criteria, the rights and responsibilities of both NGS and the customer, and the NGS process when accepting antennas for calibration.

Background:
The NGS antenna calibration techniques have been developed by the Geosciences Research Division and are conducted by the Instrumentation and Methodologies Branch of the Geodetic Services Division. Calibrations take place at NGS's Testing and Training Center. Since 1994, NGS has computed relative antenna calibrations for more than 500 antennas. These calibrations are publicly available at the web site http://geodesy.noaa.gov/ANTCAL/.

At this time, NGS provides GPS-only calibration services via the relative calibration technique, as described in this document. Users seeking absolute calibration and/or full GNSS calibration should consider IGS-certified calibration services listed at ftp://igs.org/pub/station/general/antenna_README.pdf.

Exceptions: Antennas are not eligible for relative calibration by NGS unless they can track the L1 and L2 GPS frequencies (at a minimum), possess a 5/8-11 threaded mount point, and are considered geodetic-grade equipment. Further detail is provided in the Eligibility section of this document.

Definition of Terms:

GNSS - Global Navigation Satellite System. This term generally refers to any satellite navigation system, such as the U.S.'s Global Positioning System (GPS).

Antenna Calibration - An antenna calibration is the act of determining the point of reception of the GNSS carrier phase signals. Antenna calibrations are necessary to obtain the most precise and accurate GNSS positions possible. Antenna hardware such as the antenna elements and pre-amplifiers create signal phase advance and delay before the signal is passed to the receiver. The phase advance/delay changes the range measurement,

and will introduce error to position solutions. The point of signal reception of an antenna is not a physically measurable location, and varies depending upon the direction of the satellite signal being received. Therefore antenna calibrations create a map of phase advance and delay which depends on the satellite position in an antenna-centric frame.

Relative calibration - Phase center determinations from a stationary test pier referenced to a standard (Dorne Margolin choke ring antenna, type T: AOAD/M_T).

Absolute calibration - Robot calibration, where PCO/PCV are independent of the reference antenna.

Type mean calibration - Calibration values for an antenna model, where several test samples are separately calibrated and averaged together.

Individual calibration - Calibration values which are specific to the antenna serial number; at NGS, individual calibrations are conducted on a special case basis (see *Calibration Eligibility*).

Provider - Individual or organization submitting eligible antennas for calibration.

NGS Calibration Team – NGS staff conducting calibrations.

PCO - Average phase center offset, given in north-east-up components relative to the antenna reference point (ARP), one set of components for each frequency calibrated.

PCV - Phase center variations; may be provided as a function of elevation angle in the antenna frame (1D), or elevation and azimuth angle in antenna frame (2D), one table of variations for each frequency calibrated.

ARP - Antenna reference point, a non-detachable physical reference point on the antenna, to be defined by NGS. This is usually an easily accessible point on the lowest non-removable horizontal surface of the antenna. Typically, the ARP coincides with the axis of attachment of the antenna to a monument or surveying instrument.

NRP - North reference point, some physical feature on the antenna which must be oriented toward the true north direction. Proper application of antenna calibration values in processing software assumes that the NRP is properly oriented to true north.

Clones - Identical antennas that are marked, labeled and sold as different models, usually under different brand names.

Antenna group - Three or more identical eligible antennas (may include clones).

IGS – The International GNSS Service, a voluntary federation of over 200 self-funding agencies, universities, and research institutions in more than 100 countries that creates precise GNSS orbit and clock products, global ionosphere maps, antenna calibrations, file formats, etc. (see http://www.igs.org/).

ANTEX format - ANTenna EXchange Format, used to distribute antenna calibration values; see ftp://igs.org/pub/station/general/antex14.txt for format description.

ANTINFO format - Format historically used by NGS to distribute relative calibration values for GPS only; see Help Links at http://geodesy.noaa.gov/ANTCAL/ for format description.

Antenna - the focus or object of the calibration; a single product which includes the antenna element (device or portion of a device that converts electromagnetic waves to electronic signals for use by a GNSS receiver) and antenna housing. The antenna is either:

- **modular** and must be manually connected to a separate receiver, or
- **integrated**, where it is hardwired to a receiver and marketed as a single antenna/receiver unit.

Manufacturer - the company name or **brand** prominently displayed on the antenna

Antenna code ($\leq$ 15 characters) - combined manufacturer's code and model code.

- 3 characters for manufacturer (**brand**)
- up to 12 characters for antenna model

Antenna type (exactly 20 characters and spaces) - Combination of the Antenna Code and Radome Code, used to uniquely identify an antenna and its calibration values.

1-15	Antenna code (varies in length, spaces appended as needed)
16	Space (required)
17-20	Radome code

Radome code – a unique, four-character alpha-numeric string listed in the rcvr_ant.tab file (link below). For unlisted radomes, Providers may suggest a code.

See the IGS format for antenna and radome code naming conventions at ftp://igs.org/pub/station/general/rcvr_ant.tab and "TYPE" description in ftp://igs.org/pub/station/general/antex14.txt.

(Antenna) Description - A short description of the antenna, used as an antenna description comment on the NGS website and in the ANTINFO and ANTCAL files. When possible, the Description should clearly and concisely reflect important elements of the label, such as model name, model number, part number, etc. These serve to positively identify the antenna for the user and help to differentiate between similar models or model upgrades. Descriptions are drawn primarily from the IGS file ftp://igs.org/pub/station/general/rcvr_ant.tab.

Radome - A removable cover/cap available for some antennas, most often hemispherical or conical in shape. Radomes affect the calibration results. Therefore, all Antenna Type codes must indicate whether or not a radome was used during the calibration. If no radome is used, then it will be listed explicitly as "NONE".

NGS Antenna Calibration Procedures

Calibration Eligibility

Antenna Provider eligibility

- Antenna Providers are typically vendors or manufacturers serving the precise positioning communities, which include but are not limited to: surveyors, GIS users, university researchers, federal and state agencies, and civil engineering firms. In short, almost anyone who can provide an eligible antenna group, and is willing to fully cover shipping to and from the NGS facility, is welcome to participate.
- Antenna shipments are subject to import and export controls determined by the U.S. State Department in effect at the time of the request.

Antenna eligibility

- Eligible antennas are intended for geodetic applications. Antennas for machine control and other non-geodetic applications are not acceptable.
- The NGS relative calibration equipment requires a 5/8-11 mount as the primary mounting system. Other mounting styles may be calibrated, with prior approval from NGS.
- Eligible antennas are sales-ready models where each sample provided for calibration possesses labels and markings as described below. In general, NGS will not accept pre-production or prototype models for calibration services.
- Sample antennas used to determine calibration values for an Antenna must be marked and labeled the same way production models will be marked and labeled for sale to end users. These markings and labels serve as antenna identifiers, and include brand name and one or more of the following: a model name, a model number, any revision number, and/or a part number. NGS will display a photograph of the test antenna's label with the calibration on the NGS website.
- Limited individual calibrations will be conducted by special request only. Acceptable individual calibration reasons include university research and antennas believed to deviate from the type mean value. Individual calibrations will be scheduled as allowed by the type mean calibration schedule. Contact NGS at NGS.AntCal@noaa.gov to inquire about individual calibration.
- At a minimum, antennas must receive both GPS L1 and GPS L2 frequencies.
- Preferably, antennas will have a standard RF connector for use with an external receiver. If the antenna does not have a standard RF connection and instead uses an internal/integrated receiver, data from that receiver must be made easily available to NGS Calibrations in the RINEX 2.x format. To do this, the Provider may (1) make arrangements with NGS to translate the raw data into RINEX, or (2) provide a device configured to download raw data and translate into RINEX, with contact information for a technician who can guide NGS through software usage, or (3) send a technician to NGS's Testing and Training Center to download and translate data during calibration. While an integrated receiver may not prevent relative calibration of these units, it will significantly retard progress of the units being calibrated. The NGS may assign these antennas a lower priority.
- The NGS will no longer copy calibration data from an existing Antenna Code to create a calibration for a different Antenna Code. Claims by an Antenna Provider that a new model number is identical to a previously calibrated model (i.e. clones or revisions) will be taken under advisement, but no longer be assumed and must be demonstrated. See Clones Calibration section for more information.

Clone Calibrations

Clones are identical antennas which are marked, labeled and sold as different models under different brand names. Manufacturers may request that a Clone calibration be included in the NGS calibration database under a separate Antenna Code, but the identical nature of the

originally calibrated antenna and the Clone must first be definitively determined. This section outlines how NGS will test and potentially publish Clone calibrations.

- Case 1: For a clone whose counterpart has been previously calibrated by the NGS, the Antenna Provider may submit a single clone antenna. The Antenna Provider must confirm that the clone is identical in every way (except markings and labels).
    - If the sample antenna's results compare favorably to the previously calibrated antenna group (within the RMS of the type mean or measurement error), the new sample is considered a true clone. NGS will average the new sample with values from the original Antenna Code and publish this new type mean under the new Antenna Code. The original Antenna Code and published values will not be modified.
    - If the sample antenna's results are outside the RMS of the type mean or measurement precision of the previous model, the sample is not a valid clone. The Provider will be notified and asked to submit at least two more samples for a new type mean calibration. Without additional samples, the calibration will be canceled.
- Case 2: If a manufacturer confirms that two or more antenna models are identical in every way (except markings and labels), a mix of these antenna models may be submitted as the group of 3-5 antennas normally submitted. The antennas will be treated as a single antenna group. If individual results compare favorably (RMS of type mean < about 1mm), the data will be averaged and published under each new Antenna Code. Poor comparisons (RMS > about 1mm) may require additional samples be submitted.

Rights and Responsibilities (R&R)

<u>Antenna Provider R&R</u>

- By submitting antennas for calibration, the Provider agrees to have calibration values made publically available and published to the NGS ANTCAL website. Exceptions for research purposes may be made at NGS's discretion.
- For type mean calibrations, Antenna Providers will submit an antenna group with a minimum of 3 and a maximum of 5 antenna samples. Multiple antennas are required to estimate variability within a manufacturer's model run.
- Antenna Provider will only submit antennas that are in good health. Calibrations will not be conducted for antennas that NGS determines to be in poor condition.
- Antenna Provider pays for shipping to and from the NGS Testing and Training Center. We strongly prefer that shipping be done via Federal Express (FedEx) or United Parcel Service (UPS); for other shipping services, the Provider must schedule the shipping service's pickup for return shipment. Providers outside of the U.S. must provide all international return shipping paperwork for all packages. See Shipping for additional detail.

- Provider is responsible for proper packaging for roundtrip shipping of the antennas. NGS is not responsible for damage during shipping.
- Provider must submit a high quality CAD (computer-aided design) drawing of the Antenna being calibrated. The drawing will include top, bottom and side views which will be used to unambiguously identify the Antenna Reference Point (ARP) and North Reference Point (NRP). Dimensions are optional, but are helpful to antenna calibration users for identifying an Antenna. When dimensions are included, meters must be used for the units.
- Some antennas are equipped with a removable radome and the provider may request two calibrations; one with the radome and one without.
- After calibration is completed, NGS will notify the Provider by email that the calibration has been published.
- Provider is encouraged to suggest the following codes, understanding that NGS may modify the Provider's suggestion:
    - *Antenna Code*. Must 1) comply with IGS naming conventions (see Terms of Reference), 2) be unique, and 3) be directly traceable to the markings or labeling found on the submitted antennas. The Model code should include the model/part number of the antenna and a revision number, if applicable. Note that many common brands already have a designated Manufacturer/Brand code, see ftp://igs.org/pub/station/general/rcvr_ant.tab
    - *Radome code.* (if applicable) that is consistent with the labeling. Note that many common radomes have codes assigned in the "Antenna Domes" section of ftp://igs.org/pub/station/general/rcvr_ant.tab
- All calibration values are publicly available via the Internet at https://geodesy.noaa.gov/ANTCAL/. Requests for calibration values to remain private to the Provider will not be honored.

NGS Calibration's R&R

- NGS will make a best effort to calibrate submitted antennas, but Providers should recognize that antennas may be returned to the Provider without calibration results if the calibrations have poor statistics, or the submitted antenna is not deemed survey-grade.
- NGS conducts calibration free of charge; calibration does not include antenna shipping costs (see Provider R&R)
- NGS will respond with comments or instructions to every submission of the online https://geodesy.noaa.gov/AntCalRequest/.
- NGS schedules calibrations on a first-come, first-served basis determined by the date antennas are received at the Testing and Training Center.
- NGS will communicate with the Provider about schedule delays or changes.
- Calibrated antennas will be published to the NGS website. Calibration values are expressed as PCO and PCV components, and will be distributed in multiple formats (ANTINFO and ANTEX formats).

- NGS will consider suggestions for Antenna Codes for the submitted antennas, but will make the final decision on the codes upon coordination with the IGS Antenna Working Group. The final Antenna Code will be based upon a combination of physical information (markings and labeling) from the antennas submitted and information submitted in the Calibration Request form.

Calibration Process

1. Fill out the request form at http://geodesy.noaa.gov/AntCalRequest/. First-time visitors to this website will have to register as an Antenna Provider. You will be asked for contact information, shipping address, and detailed information on the antennas being submitted (for example, brand, model number, number of antennas being sent).
2. After review of the initial request, the Antcal Manager will contact the Provider. Scheduled dates are approximate.
3. Provider ships antennas to:

Company:	NOAA's National Geodetic Survey
Department:	Antenna Calibrations
Street address:	15351 Office Drive
City:	Woodford
State:	Virginia
Postal code:	22580
Telephone:	1-540-373-1243
Email:	ngs.antcal@noaa.gov

4. After completing calibration, NGS
    a. publishes calibration values to the NGS Calibrations website,
    b. emails the Provider to notify them that the calibration has been published, and,
    c. in original packaging, prepares antennas for return shipment. Shipping arrangements and costs are the responsibility of the Provider.

Shipping

Shipping charges, all shipping-related fees, and customs paperwork, both to and from the NGS facility, are separate from the calibration service and are the responsibility of the Antenna Provider. Providers must understand that we are an antenna calibration service, not a professional shipping service. To ensure antennas are returned, Providers must properly complete and include with the shipment a Commercial Invoice (three copies) and any other required documents. It is not possible for the NGS to know what it will take to get antennas back into a particular country.

In addition to handling Customs issues, Providers are also expected to do one of the following:

1. Include prepaid return air bill(s) with shipment. The carrier must be able to pick up packages at our facility.
2. Attach prepaid air bill(s) in PDF format to an email. Again, the carrier must provide pickup service.
3. For U.S. destinations only, you may provide a valid UPS or FedEx account number. We cannot use account numbers from any other carrier. If the number will not work in the carrier's online shipping service, we will notify the Antenna Provider to make other arrangements.

Contact

Questions regarding these procedures and antenna calibrations in general may be directed to NGS.antcal@noaa.gov. We welcome and appreciate feedback on these procedures and NGS's antenna calibration services.

RECORD OF REVIEW AND CHANGES

This is a living document that is reviewed every two years. It will be updated, when appropriate, to reflect changes in controlling Federal policies, organizational strategic goals/objectives, technology, or other matters that may have an impact on these procedures. Modifications made to this document are recorded in the below table. This record shall be maintained throughout the life of the document.

Version Number	Date	Section/ Page Affected	Summary of Change or Annual Review	Author / Reviewer
A1	9/20/2016	ALL	Entire policy revised to meet new NGS administrative requirements and incorporate any updates	GSD/GRD
A2	5/15/2019	3,4,8,9	Definition of terms, antenna coding, NGS rights and responsibilities, shipping address, web links updated	GSD/GRD